ORIGINAL ARTICLE

Association between road vehicle collisions and recent medical contact in older drivers: a case-crossover study

Sandy Leproust, Emmanuel Lagarde, Samy Suissa, L Rachid Salmi

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See end of article for authors' affiliations

Correspondence to: Professor L R Salmi, ISPED, Université Victor Segalen Bordeaux 2, 146, rue Léo-Saignat, F-33076 Bordeaux cedex, France; rachid.salmi@isped.u-bordeaux2.fr

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Objective: To estimate the association between past medical contacts and the risk of vehicle collision in a population of older drivers from the province of Quebec, Canada.
Design: Case-crossover study.
Setting: Quebec.
Participants: 111 699 older drivers involved in at least one vehicle collision between January 1988 and December 2000.
Main outcome measures: For each driver, the risk of having a vehicle collision while exposed and not exposed to a medical contact was compared. Separate conditional logistic regression analyses were conducted for all drivers and in four diagnostic-specific subgroups.
Results: The study found a weak but statistically significant increased risk of all collisions being associated with a medical contact within 1 month before the collision, for all drivers (OR = 1.10, 95% CI 1.08 to 1.11) and for drivers with diabetes (OR = 1.07, 95% CI 1.03 to 1.11).
Conclusion: Older drivers who have a collision are more likely to have been in contact with a physician shortly before the collision. These findings suggest that there might be an opportunity to detect medical conditions that put older drivers at higher risk of collision; however, further research is needed to assess the potential effectiveness and practical modalities of screening.

By 2030, one-quarter of the population in the member countries of the Organization for Economic Co-operation and Development will be aged 65 years and older.[1] Ageing of populations in industrialized countries implies an increase in the proportion and number of older drivers. In the USA, for instance, there were 19.9 million older drivers in 2002, and their police-reported collision involvements are expected to increase by 178% by 2030.[2 3] The proportion of licensed drivers aged 65 years and over is expected to increase from 12.6% in 2000 to 22.1% in 2030 in Australia, 12.6% to 20.0% in the USA, 15.7% to 23.5% in the UK, 16.1% to 25.8% in France, and 12.6% to 22.8% in Canada.[1] In 2001, in the province of Quebec, there were almost one million people aged 65 and over (13.3% of the population), of whom 32.5% had a driving license.[4 5] In this province, there were 4065 severe vehicle collisions; 13% involved older drivers, who were also involved in 15% of lethal collisions.

Many studies have assessed the relationships between age and the risk of collision. In 1995, Foley *et al*[6] showed that age was not significantly associated with the risk of collision, but many other studies supported the suggestion that age was associated with being involved in a collision.[3 7–10] Even if age were clearly associated with the risk of collision involvement, the association is not strong enough to predict which drivers will actually be at higher risk of being involved in a collision. Nevertheless, the increase with age of the prevalence of medical conditions that may impair driving ability could logically put older drivers at higher risk of collision.[11–13] Many studies have shown that there is a high prevalence of cognitive impairment in older drivers involved in vehicle collisions; older drivers with dementia (Alzheimer's type) are also at higher risk of vehicle collision.[14–16] Studies on driving resumption after a traumatic brain injury (TBI) found that a subject who suffered from severe TBI has a significantly higher risk of being involved in a road traffic collision.[17 18] Many authors have suggested that these patients should be assessed for both mental and physical status before they resume driving.[17 18]

Consequently, some countries, states and provinces have adopted standard or age-based license renewal procedures,[19–21] and adoption of similar policies is debated in some countries in Europe.[22] These procedures are often simple administrative renewal of the license; in other places, applicants must perform tests such as vision tests or even road tests when specific medical conditions are present.[19–21] In the USA, in-person license renewal was related to a lower fatality rate among the oldest drivers, with the relative incidence decreased by 17%.[23] However, other studies assessing mandatory evaluations targeting older drivers to prove their fitness to drive[23 24] or education programs[25] did not show a reduction in collisions or an increase in safety of older impaired drivers. The extension of similar interventions raises many issues. Beyond the validity of the tests, one key problem is to define the best opportunity for assessing ability to drive—for example, early diagnosis among all drivers in the general population or at the time of driver license renewal (systematic screening) or assessment during medical contacts for other reasons (case-finding); another is to decide what would be the role of health professionals in the detection and reporting process.

Assuming that any contact with a physician could be an opportunity to reach drivers with medical conditions associated with unsafe driving and thus detect drivers at risk of vehicle collisions, we performed a case-crossover study to estimate the association between a medical contact and the risk of road vehicle collisions in a population of older drivers from the province of Quebec, Canada.

METHODS

Participants

All older drivers (licensed drivers aged 65 years and older) from the province of Quebec, Canada, with a valid driving license

Abbreviations: RAMQ, Quebec Health Insurance Agency; SAAQ, Universal Quebec Automobile Insurance Agency; TBI, traumatic brain injury

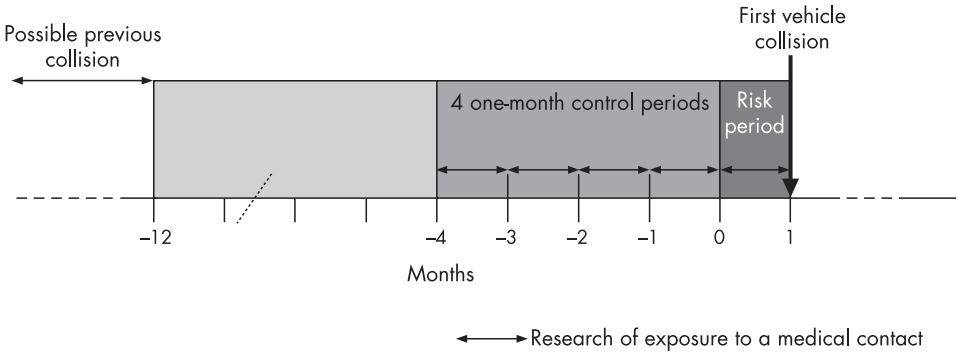

Figure 1 The case-crossover design used in the study of the association between road vehicle collisions and recent medical contacts in older drivers from the province of Quebec, Canada (1988–2000).

and involved in a vehicle collision from 1988 to 2000 were eligible for this study. Eligible drivers were identified using the databases of the Universal Quebec Automobile Insurance Agency (SAAQ) and the medical file of the Quebec Health Insurance Agency (RAMQ). The SAAQ is responsible for driver's license registration and recording reports of motor vehicle collisions. Its databases, available from 1985 to 2000, contain information on the driver (age, sex) and allow the validity of the driver's license to be checked. They also contain information on collisions (date, kind of road, environmental conditions, severity, and number of victims involved). We obtained medical data from the RAMQ, which is responsible for healthcare services for the province. These databases provide information on the practitioner (specialty, class, and establishment), on the act (code, date, and amount) and on the diagnosis (code). In all databases, drivers have a unique identifier and it was possible to cross-check information on both collisions and medical visits.

Design

The case-crossover design[26] is appropriate when a brief exposure (medical contact) is associated with an increase in the risk of an acute event (the collision). Each driver is his/her own control, and therefore confounding due to fixed characteristics of the driver is eliminated.

Time of collision

Because the RAMQ databases were only available from 1988, only collisions after 1988 were considered for inclusion. The time of collision (index date) was defined as the date of the first collision that occurred between 1988 and 2000. To provide equal availability of control time periods to all subjects (see the definition of control periods below), the index date was to be preceded by a collision-free period of at least 12 months. In a first analysis, we considered all first collisions. As severe collisions are unlikely to be under-reported,[27] we also restricted a secondary analysis to severe collisions, defined as lethal collisions and collisions resulting in hospitalization for at least one person involved. We finally analyzed severe collisions adding material damages greater than $C500.

Hazard and control periods

We defined the risk period as the first 1-month period preceding the index date. We used as control periods the four 1-month periods preceding the risk period. We compared exposure to a medical contact during the risk period with exposure during control periods (fig 1).

Assessment of exposure

For all periods, drivers who had been in contact, at least once, with a physician (hereafter called medical visit) were considered as exposed, whatever the diagnosis associated with the visit. Because the exact time of the visit is not reported in the databases, we excluded visits on the day of the collision, to identify only exposures that occurred strictly before the time of collision. Subgroups of drivers potentially at higher risk of unsafe driving[14–18 28] were also defined, according to diagnostic codes of the International Classification of Diseases (ICD-9), as: (1) patients with diabetes (ICD code 250.0–250.7 and 250.9–251.1); (2) patients with dementia (ICD code 290.0, 290.2–290.4, 331.0, and 331.2); (3) patients with psychotic disorders (ICD code 295.0–295.9, 297.1, 301.0, and 301.2); (4) patients with consequences of TBI (ICD code 800.1, 800.3, 801.1, 801.3, 803.1, 803.3, 804.1, 804.3, 850.0, 851.0, 851.1, and 907.0).

Statistical analysis

We used a conditional logistic regression to estimate the risk of vehicle collision in drivers who had been in contact with a physician before the collision.[29] We conducted separate analyses for: all collisions, severe collisions only, and severe collisions or material damages greater than $C500. Adjusted odds ratios were estimated for all drivers and for drivers in the four diagnostic-specific subgroups. As the numbers in the diagnostic-specific subgroups of dementia, psychotic disorders, and consequences of brain injury were small in the group of severe collisions only (fig 2), the results are not presented in this paper. Finally, sensitivity analyses were carried out using different lengths and number of control periods. All the analyses were performed using SAS software V.9.

RESULTS

Study population

There were 434 389 collisions recorded by the SAAQ from 1 January 1985 to 31 December 2000 (fig 2). Almost 83% of drivers involved were men with a mean (SD) age of 66 (7.5) years. Most collisions resulted in material damages greater than $C500 (62.3%), 3% were considered to be severe collisions, and fewer than 1% were lethal.

We included in this analysis 111 699 vehicle collisions, including 3318 severe collisions, recorded from 1988 to 2000 (table 1). These collisions were most often located in business areas and resulted in material damages greater than $C500. The mean age of drivers involved was 71 (0.5) years, and 80% were men. These 111 699 collisions resulted in 33 051 victims, 86.5% of whom were slightly injured. The characteristics of collisions and drivers did not differ between the four diagnostic-specific subgroups, except for the group of drivers with dementia, where the mean age was higher (74 (5.8) years). Detailed descriptive characteristics of drivers in diagnostic-specific subgroups are available upon request to the authors.

Medical contacts

Fifty four percent of all drivers had at least one medical contact during the month preceding the collision (compared with 52%

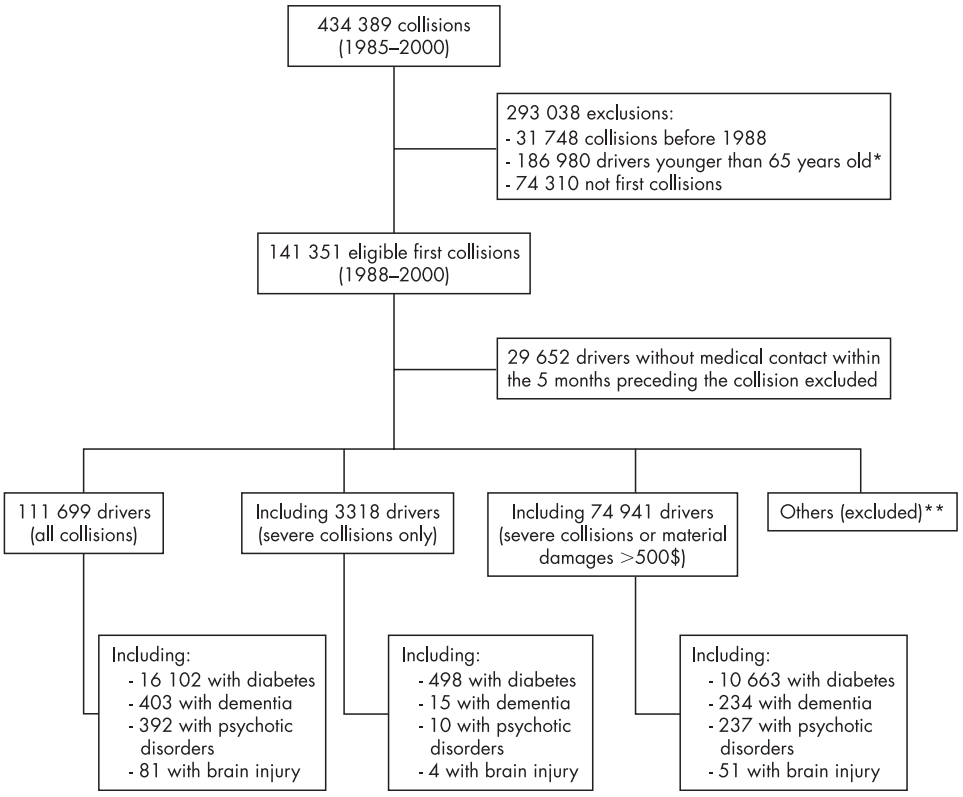

Figure 2 Numbers of drivers and collisions included in the study. *Drivers excluded because aged less than 65 years (median 60, interquartile interval 57–62) and 52 subjects with coding errors; **slight collisions and collisions resulting in material damages equal to $C500 or less.

during at least one control period). The frequency of medical contact in the risk period was higher in drivers with dementia (66%) and drivers with diabetes (60%). For drivers with diabetes, the frequency of medical contact in the control periods was the same as in the risk period (60%), whereas drivers with dementia were most often exposed during the control periods (71%).

There was a weak but statistically significant increased risk of all collisions associated with a medical contact within 1 month before the collision, for all drivers and for drivers with diabetes (table 2). This weak and statistically significant association was also observed for severe collisions or material damages greater than $C500, for all drivers and drivers with diabetes. In the group of severe collisions only and in the other diagnostic-specific subgroups, there was no significant association between the risk of collision and recent medical contacts.

Sensitivity analyses

Changing the length and number of study periods did not affect the results, except when a risk period of 2 months was matched with two control periods (table 3). With the increased power derived from this matching, a borderline statistically significant

Table 1 Characteristics of vehicle collisions in which older drivers were involved in the province of Quebec, Canada (1988–2000)

Variable	All collisions (n = 111 699)	Severe collisions only* (n = 3318)	Severe collisions or material damages > $C500 (n = 74 941)
Collision severity			
Material damages (⩽$C500)	18 364 (16.4)	NA	NA
Material damages (>$C500)	71 623 (64.1)	NA	71623 (64.1)
Injury without hospitalization	18 394 (16.5)	NA	NA
At least one hospitalized victim	2802 (2.5)	2802 (2.5)	2802 (2.5)
Lethal	516 (0.5)	516 (0.5)	516 (0.5)
Victims involved			
All	33 051 (100.0)	6618 (100.0)	6618 (100.0)
Slightly injured	28 590 (86.5)	3849 (58.2)	3849 (58.2)
Seriously injured	3849 (11.6)	2157 (32.6)	2157 (32.6)
Dead	612 (1.9)	612 (9.2)	612 (9.2)
Sex (men)	89 301 (80.0)	2730 (82.3)	60095 (80.2)
Age			
Mean (SD)	71 (5.0)	72 (5.3)	71 (5.0)
Median (interquartile interval)	70 (67–74)	71 (68–75)	70 (67–74)
At least one medical contact			
Risk period	60 556 (54.2)	1780 (53.6)	40 341 (53.8)
Control periods	58 219 (52.1)	1746 (52.6)	38 786 (51.7)

NA, not applicable.
Unless otherwise indicated, values are number (%).
*Lethal collisions and collisions involving at least one hospitalized victim.

Table 2 Adjusted risk of vehicle collision associated with a previous medical contact in older drivers from the province of Quebec, Canada (1988–2000)

	n	OR (95% CI)*	p Value
All collisions			
All drivers	111 699	1.10 (1.08 to 1.11)	<0.001
Drivers with diabetes	16 102	1.07 (1.03 to 1.11)	<0.01
Driver with dementia	403	0.94 (0.73 to 1.21)	0.62
Drivers with psychotic disorders	392	1.13 (0.88 to 1.47)	0.33
Drivers with consequences of brain injury	81	1.31 (0.76 to 2.33)	0.33
Severe collisions only†			
All drivers	3318	1.05 (0.97 to 1.13)	0.26
Drivers with diabetes	498	0.93 (0.75 to 1.15)	0.51
Severe collisions or material damages greater than $C500			
All drivers	74 941	1.10 (1.08 to 1.12)	<0.001
Drivers with diabetes	10 663	1.07 (1.03 to 1.12)	<0.01
Driver with dementia	234	1.02 (0.73 to 1.42)	0.92
Drivers with psychotic disorders	237	1.04 (0.75 to 1.44)	0.70
Drivers with consequences of brain injury	51	1.18 (0.60 to 2.34)	0.63

*Odds ratios (ORs) with 95% confidence intervals determined by conditional logistic regression.
†Lethal collisions and collisions involving at least one hospitalized victim.

association was observed for all drivers in the group of severe collisions only (OR = 1.10, 95% CI 1.01 to 1.20).

DISCUSSION

We found evidence of a slightly increased risk of all vehicle collisions associated with a medical contact within 1 month before the collision, for all drivers and for drivers with diabetes. The same result was observed in the group of severe collisions or material damages greater than $C500, but not in the group including severe collisions only. Thus, older drivers who have a collision, especially those with diabetes, are more likely to have been in contact with a physician shortly before the collision.

Strengths and potential limitations of the study

The case-crossover design is efficient, as it does not require a control group and, as each case is his/her own control, it neutralizes possible confounding effects due to long-lasting characteristics of the driver.[26 30] One limitation of this design is the assumption that exposure to potential confounding due to unstable factors other than the exposure of interest is the same in both risk and control periods. For instance, we implicitly assumed that drivers had the same driving patterns in both the risk and control periods. If study subjects did not drive during the control periods, they were obviously not at risk of being involved in a vehicle collision, resulting in a possible overestimation of the association between medical contacts and the risk of collision. However, we think it more plausible that, if the risk of collision were related to aggravation of a medical condition, older drivers would be more likely to decrease their driving just before the collision. Indeed, drivers often adopt self-regulation strategies whenever they are aware of their diminishing ability to drive,[31 32] therefore would be more likely to stop driving during the risk period, resulting in an underestimation of the association.

Table 3 Sensitivity analyses of the estimation of the risk of vehicle collisions associated with a previous medical contact in older drivers (all older drivers and drivers with diabetes) from the province of Quebec, Canada (1988–2000)

	Sample size*	Control periods n	Control periods Length†	Total study period (months)‡	Exposed in the risk period (%)§	OR (95% CI)¶
All collisions						
All drivers	111 699	1	2	4	75.6	1.10 (1.08 to 1.12)
	115 468	2	2	6	73.2	1.15 (1.13 to 1.17)
	111 699	4	1	5	54.2	1.10 (1.08 to 1.11)
	111 699	9	0.5	5	32.9	1.00 (0.99 to 1.02)
Drivers with diabetes	16 768	2	2	6	76.2	1.12 (1.07 to 1.17)
	16 102	4	1	5	60.2	1.07 (1.03 to 1.11)
Severe collisions only						
All drivers	3429	2	2	6	72.3	1.10 (1.01 to 1.20)
	3318	4	1	5	53.6	1.05 (0.97 to 1.13)
Drivers with diabetes	507	2	2	6	77.9	1.18 (0.90 to 1.56)
	498	4	1	5	57.8	0.93 (0.75 to 1.15)
Severe collisions or material damages > $C500						
All drivers	77 490	2	2	6	72.8	1.15 (1.13 to 1.17)
	74 941	4	1	5	53.8	1.10 (1.08 to 1.12)
Drivers with diabetes	11 102	2	2	6	76.1	1.10 (1.05 to 1.15)
	10 663	4	1	5	60.5	1.07 (1.03 to 1.12)

*Sample size can vary in the same group because duration of the study depends on the length of the observation period and the number of control periods.
†Length of each control period (months).
‡Total study period = risk period + control periods.
§At least one medical contact during this period.
¶Odds ratios (ORs) with 95% confidence intervals determined by conditional logistic regression.

As we did not know the exact time of collision, we excluded drivers who had been in contact with a physician on the day of the collision, to avoid misclassification related to the inclusion of medical contacts that actually occurred after the collision. By doing so, we probably also excluded drivers who had a medical contact just before the time of collision. The exclusion of these drivers, who were plausibly at higher risk of collision, may have led to an underestimation of the association between relevant medical contacts and the risk of collision.

In a case-crossover design, the total hazard period is defined as a time interval after a trigger, when the subjects experience an increased risk of the outcome.[30] This hazard period may be divided into several periods of different degrees of excess risk. The risk period corresponds to the period when the incidence rate of the outcome is supposed to be increased. In our study, we assumed that the length of the risk period, in which a medical contact was hypothesized to be associated with a vehicle collision, was 1 month. The sensitivity analyses performed indicate that this length of risk period used with four matched control periods was a satisfactory design in this population of older drivers from Quebec. However, beyond the effect on statistical significance, it is obvious that a medical evaluation repeated monthly to detect drivers with at-risk medical conditions would not be possible in practice.

One reason why some associations were not statistically significant is the lack of statistical power in three of the diagnostic-specific subgroups. Indeed, numbers in the subgroups of dementia, psychotic disorders, and consequences of TBI were very small. Thus, a screening program targeted at a rare diagnostic-specific subgroup to prevent a rare event, such as a collision, would necessarily have a weak effect.

Conclusion and implications for prevention

Our findings suggest that there might be an opportunity, during routine medical visits, to detect medical conditions that put older drivers at higher risk of vehicle collision. However, a medical contact, defined as a medical visit, is only an indirect indicator of the opportunity to detect high-risk older drivers. The actual detection implies that the medical visit should include an evaluation of driving competency, but reliable, valid, and applicable screening tools to predict actual ability to drive remain to be developed. Published studies suggest that only on-road assessment tests are reliable and valid tools for determining driving competency.[15 33–37] However, these tests are time-consuming, expensive,[22] and not necessarily appropriate for older drivers because they are based on driving skills sometimes over-learned by the older driver.[35 37] In the hypothesis that reliable and valid tests could be developed, other issues need to be resolved before a screening program could be implemented. Firstly, it needs to be decided whether the role of the physician would be based on a voluntary or mandatory reporting system; the level of mandate could dramatically modify the participation of physicians. Secondly, once unsafe driving is detected, it is not obvious what would be the most effective intervention to reduce the risk of collision. Different kinds of interventions, more or less restrictive, have been suggested in the literature, including educational or training programs, driving restrictions (geographic areas, time and day limitations), and complete ban on driving. Uncertainty about the effectiveness of these interventions is due to the negative effects potentially related to driving restrictions.[35 38] In the specific case of older drivers, potential negative consequences of a reduction in driving opportunities could be an increase in dependency, isolation, and depression.[37 39 40] Ultimately, a screening program should be recommended only if the positive effects outweigh the negative effects. This uncertainty is a likely reason why recent studies have recommended helping older drivers to maintain ability to drive safely rather than simply removing authorization to drive.[25] Whatever the kind of intervention and context of implementation, the ability to demonstrate that a medical contact is associated with an increased risk of collision could thus represent an opportunity to detect drivers potentially at risk of collision, and remains an important step for policy making.

Key points

- Although older drivers seem to be at higher risk of collision per mile driven, many authors suggest that, instead of age itself, it is the increase with age of medical conditions that may impair driving that could put older drivers at higher risk of collision.
- Recent medical contacts (within 1 month of a collision) were significantly associated with an increased risk of collision for all drivers and drivers with diabetes.
- Any medical contact could represent an opportunity to detect medical conditions that put older drivers at higher risk of collision.
- Further research is needed to assess the potential effectiveness and practical modalities of potential systematic screening programs to detect unsafe driving caused by medical conditions.

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Authors' affiliations

Sandy Leproust, Emmanuel Lagarde, L Rachid Salmi, INSERM, U593, Équipe Avenir Santé et Insécurité Routière, ISPED, Université Victor Segalen Bordeaux 2, Bordeaux, F-33000, France
L Rachid Salmi, CHU Bordeaux, Service d'information médicale, Bordeaux, F-33000, France
Samy Suissa, Division of Clinical Epidemiology, Royal Victoria Hospital, McGill University Health Centre, West Montreal, Quebec H3A 1A1, Canada

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LACUNAE

China says coal-mining deaths up 21%

The number of deaths in China's incident-plagued coal mines surged by nearly 21 percent in the first 3 months of this year, despite a national safety crackdown, the country's top industrial safety official said in April.

Fires, cave-ins and other incidents killed 1113 miners between January and March, up 20.8% over the same period in 2004, said Li Yizhong, the minister in charge of the State Administration for Work Safety. ''Since the fourth quarter of last year, several particularly serious accidents have occurred, arousing widespread concern of the public,'' Li said at a news conference.

In February, an underground explosion in northeast China killed 214 coal miners in the country's deadliest reported mine incident since the start of communist rule in 1949. Another incident in March killed 72 coal miners in northern China.

China's coal mines are the world's deadliest, with thousands of deaths a year blamed on lack of required equipment or indifference to safety rules. Communist leaders have repeatedly promised to tighten standards, but an average of 16 miners are killed each day.

Li said China's cabinet and communist party leadership ''have been placing great importance on issues regarding work safety''.

The agency ''has been cracking down on all kinds of illegal mining operations and rectifying mines that fail to meet work safety standards,'' he said. Efforts to shut down dangerous mines have been complicated by the country's soaring demands for power to drive its booming economy. The government has ordered emergency shipments of coal amid widespread blackouts, prompting mines to push their facilities beyond safe limits. Many smaller, unlicensed mines have reopened in response to the surging demand.

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